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A Proposal for A 48-Inch
Telescope

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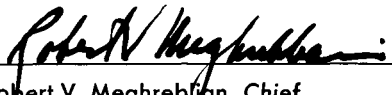
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*A Proposal for A 48-Inch
Telescope*

Space Sciences Division



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I. INTRODUCTION

In 1959 the Jet Propulsion Laboratory (JPL) was given responsibility under the National Aeronautics and Space Administration (NASA) for the unmanned exploration of the Moon, the planets, and interplanetary space. The *Ranger*, *Mariner*, and *Surveyor* programs are the immediate implementation of this responsibility. The very first formal JPL document on the space program (Ref. 1) recognized, however, that space probes were not enough; they could not do everything. Space probes are too few and too expensive, with the timing of even those few determined by the inexorable laws of celestial mechanics. Under these circumstances there is no conceivable reason for using a space probe to do any job which can be accomplished using ground-based observing techniques.

The first firm step toward overcoming the very serious

deficiency in the space program created by the lack of a ground-based observing program was taken early in 1961 with the creation of a small group of astronomers in the Space Sciences Division at JPL whose principal interests have been in the field of planetary astronomy. This group has made significant progress, utilizing data existing in the United States and obtaining new data, chiefly through the cooperation of colleagues in Canada.

The second step was taken in the Fall of 1961 with the acquisition of a small telescope and negotiation for an observing site at Table Mountain, California (Fig. 1). These negotiations were successfully completed, and construction of the first unit of Table Mountain Observatory began in the Spring of 1962 (Refs. 2, 3). The observatory was completed (Figs. 2 and 3) and recently began its

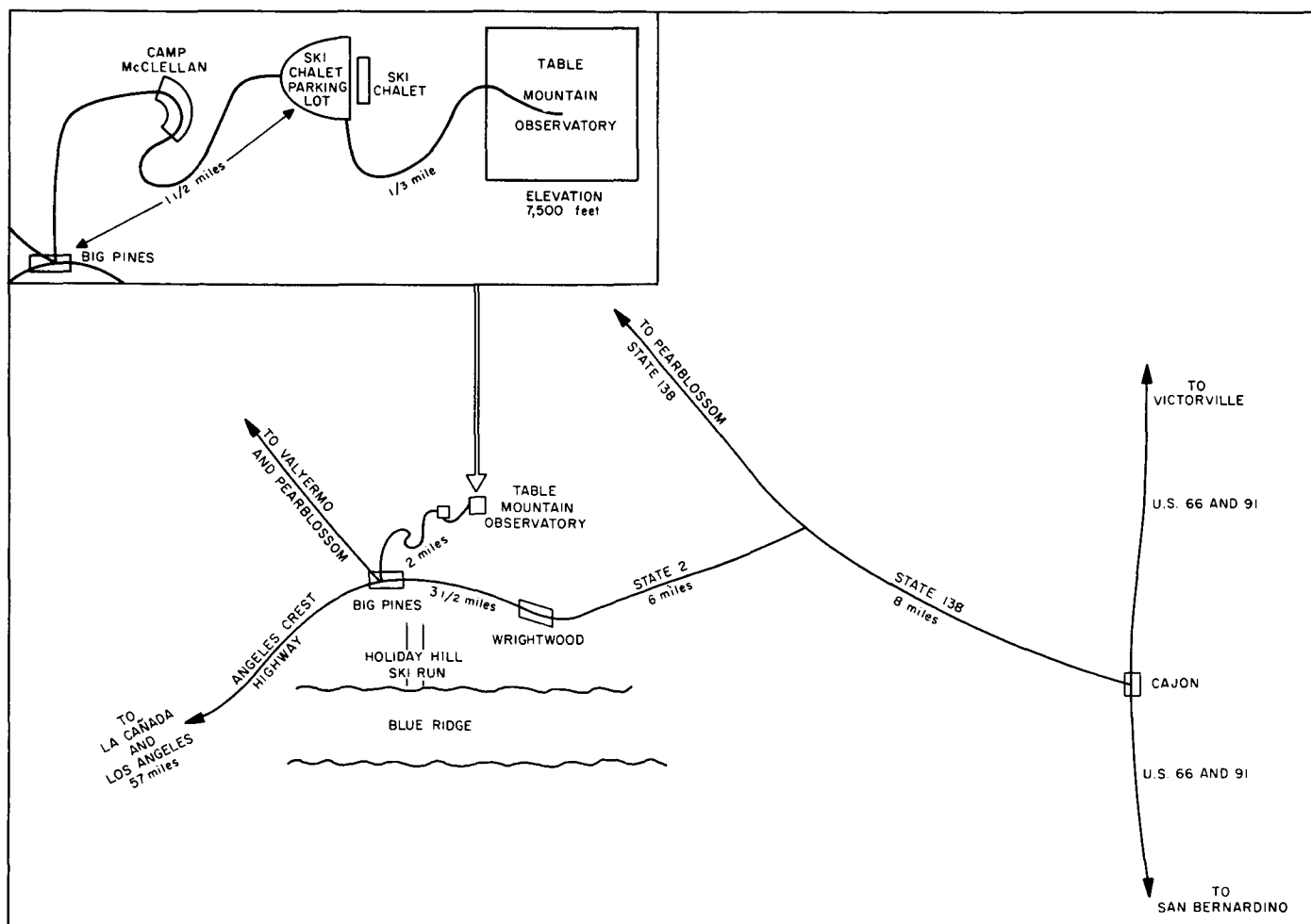


Fig. 1. Approaches to Table Mountain, California

first major program on the Venus inferior conjunction of November 1962. Meanwhile, the Lunar and Planetary Sciences Section of the Space Sciences Division has grown to significant strength and is now prepared to undertake the next major step in the realization of the responsibilities inherent in the contract, charging JPL with the major task of conducting unmanned exploration of deep space.

The Laboratory now proposes to construct a general purpose reflecting telescope of 48-in. aperture, with some

emphasis, however, being given to its special suitability for infrared spectroscopy, an area critically needing work in modern planetary astronomy. A more detailed background, the outline of a program, equipment needs, a cost estimate, and a personnel survey are included in this proposal.



Fig. 2. Sixteen-inch dome, office building in background, Table Mountain Observatory

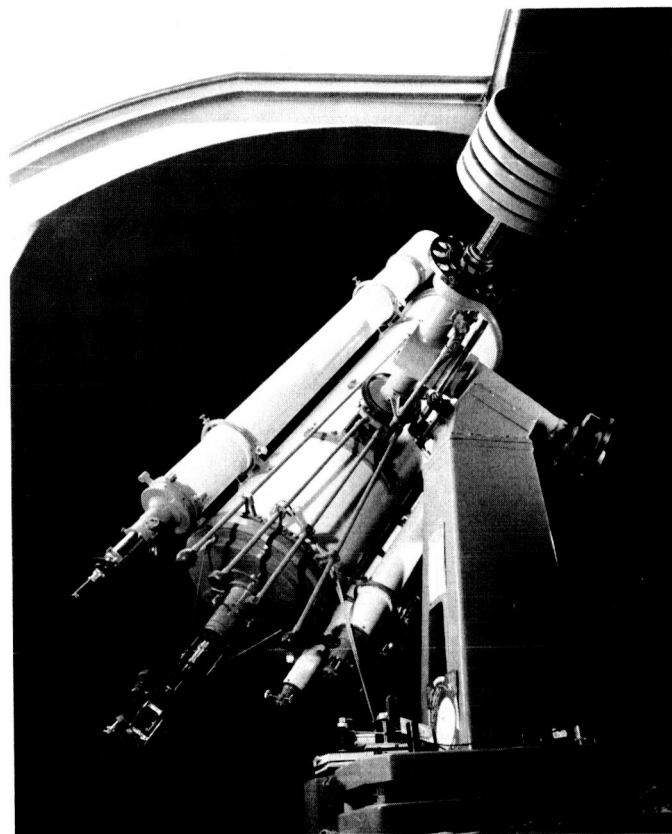


Fig. 3. Sixteen-inch Cassegrain reflector set up for lunar probe impact photography, Table Mountain Observatory

II. PLANETARY ASTRONOMY

During the 17th, 18th, and 19th centuries, planetary astronomy, including its theoretical branch, celestial mechanics, made up 95 percent of astronomy. The problem of quantitatively explaining the motions of the Moon and planets forced the development of Newtonian mechanics, while the development of mechanics demanded better planetary observations.

During the 19th century physicists began to achieve a qualitative understanding of the interactions of radiation and matter. Astronomers were at last given a tool

which seemed to offer hope of some understanding of the enigmatic universe beyond the solar system. By 1907 George Ellery Hale was able to state that (Ref. 4) "In astronomy the introduction of physical methods has revolutionized the observatory, transforming it from a simple observing station into a laboratory, where the most diverse means are employed in the solution of cosmical problems." Hale proceeded to launch the new science of astrophysics in an all-out assault on the fundamental problems of stellar evolution.

During the ensuing half century astrophysicists plunged into stellar and galactic problems, never to return to the more mundane affairs of the solar system. Only the Sun received significant attention, for it is a star. In fact, planetary astronomy gradually acquired a bad reputation as a result of overly enthusiastic Sunday supplement writers and overly ardent amateur astronomers with little training in physics. Hale never intended for this to happen. He wrote that the problems of astronomical evolution could be considered solved only when we understood the formation of a planet like the Earth, that the astrophysicists' work ended only when he began encroaching on the domain of the geologist.

During the 1930's a few professional astronomers made short excursions into planetary astrophysics which re-

sulted in significant contributions. From World War II to the advent of the space program, however, the number of active planetary astronomers in the United States could be counted on the fingers of one hand, and of those, only G. P. Kuiper spent a majority of his time in the field. As a result, the eve of the space program found astronomers ill prepared to describe the solar system in anything like quantitative terms. The modern tools of astronomy, the large reflector with high dispersion Coudé spectrographs, sensitive infrared detectors for spectroscopy and radiometry, modern image orthicons and converters, etc., have rarely been applied to problems of the solar system.

It is proposed to employ the modern techniques of stellar astronomy to attack the numerous outstanding problems in lunar and planetary astrophysics.

III. THE TELESCOPE AND THE PROGRAM

The 48-in. telescope will be a modified version of the new reflector of that aperture at the Dominion Astrophysical Observatory, Victoria, B. C., Canada. However, we plan to use fused silica for the primary mirror instead of pyrex. Two photographs of the Victoria 48-in. telescope are shown as Figs. 4 and 5.

It is proposed that both Cassegrain and Coudé foci be used on the telescope; their f-ratios are $f/16$ and $f/30$, respectively. The Cassegrain focus will be used for medium-dispersion photographic and photoelectric spectroscopy, infrared radiometry, polarimetry, wide-band photoelectric photometry (for which a photometer adaptable to the 16-in. reflector has already been designed), and for direct photography. The low thermal coefficient of the fused quartz will be of considerable usefulness primarily in programs of lunar mapping and planetary photography. The five-mirror Coudé arrangement will provide a fixed focus in a horizontal Coudé room. Here we plan to install a high-dispersion spectrograph and a spectrometer for the visible and near-infrared. The fixed focus in a large Coudé room will enable us to employ extremely sensitive infrared receivers which require sophisticated cooling arrangements and are therefore unsuitable for moving focus work. For the spectrograph we plan a 180-in. collimator and cameras of 16-, 32-, and 96-in. focal length. With readily available gratings we will obtain dispersions ranging from 40 to 2 Å/mm in the red.

The initial programs will include extensions of current lunar and planetary research using spectroscopic and

photographic techniques, plus the initiation of programs in infrared spectroscopy and radiometry. Some samples of solar system problems that can be fruitfully attacked spectroscopically are mentioned below.

All the planets with atmospheres present interesting, and somewhat individual, problems. One goal of the program is to establish the molecular compositions of planetary atmospheres; even now the compositions of stellar atmospheres are better determined than those of planetary atmospheres. Part of the problem is that the abundant homopolar gases H_2 and N_2 do not *ordinarily* produce planetary spectral lines in regions accessible to Earthbound observers. However, the pressure-induced dipole bands of N_2 and H_2 and the sharp quadrupole lines of H_2 lend promise for quantitative analysis of even these molecules if they are present in large amounts (Refs. 5 and 6).

The near-infrared Venus CO_2 bands may be used for abundance, temperature, and pressure measurements (Ref. 7) and even for isotopic abundance ratios (Ref. 8). The phase dependence of these parameters is now under study, but large numbers of high-dispersion spectra are needed to convert the observational quantities into model atmospheres of some use in entry capsule design, for example. The simple question of the O_2 abundance on Venus has not yet been settled; all that is required are new spectra at the appropriate phase angles.

The outer planets also present a large number of important desiderata that may be subject to modern

spectroscopic investigation. For example, what is the abundance of water vapor on Mars? Telescopic observations from the Earth should be able to detect any Martian H_2O in excess of 60μ precipitable water; these observations just have not been tried. What are the abundances of the light gases, hydrogen and helium, in the major planets? Preliminary work here indicates that the absolute H_2 abundance above the planetary clouds increases outward from the Sun, but the H/C ratio may decrease to a value far below the corresponding cosmic ratio (derived from hot stars and the Sun). It may also be possible to establish the D/H isotope ratio in the

outer planets from the HD dipole lines in the near infrared. The C^{12}/C^{13} ratio may be found from a detailed study of the methane spectrum. It is planned to study these important problems, and, undoubtedly, many new problems, such as the variable NH_3 "wind" of Jupiter and the luminescence in lunar craters, will be found.

These examples suggest fields in lunar and planetary astrophysics which can and should be investigated from Earthbound observatories. The fact that they are not being attacked by U.S. astronomers is a justification for this proposal.



Fig. 4. Forty-eight-inch reflector, Dominion Astrophysical Observatory (by courtesy of the observatory)

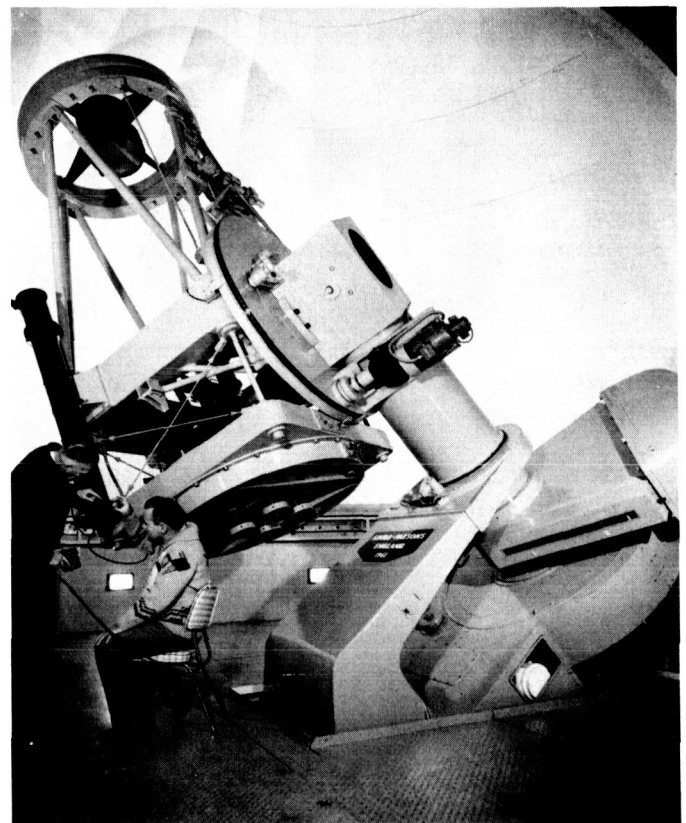


Fig. 5. Forty-eight-inch reflector, Dominion Astrophysical Observatory (by courtesy of the observatory)

IV. THE OPERATION OF THE TELESCOPE

It is proposed that the 48-in. telescope be used as an instrument for solar system research. In that capacity it would be made available to any observer with a worthwhile program in this field. It is expected that other NASA centers and the rest of the scientific commu-

nity as a whole have potentially great interest in solar system physics and will wish to use these facilities. In fact, this philosophy is being adopted in the programming of the Table Mountain 16-in. reflector now in operation.

V. SITE SELECTION

It is proposed to use the 1962-1963 results with the 16-in. reflector at Table Mountain to determine the suitability of the site with respect to total clear night hours and seeing. Table Mountain is probably one of the best sites in the western U.S.; the site is far enough from the metropolitan Los Angeles area to be quite free of smog and city lights, and it is both high and dry enough to make possible spectroscopic searches for water vapor on Venus and Mars. The fact that the Table Mountain site

is already physically developed (Fig. 6) is a great financial advantage, but in the contingency that this site does not prove feasible, it is still possible to use the results of the 200-in. and Kitt Peak surveys for another site selection.

The specific location of the 48-in. telescope on Table Mountain will depend upon the results of a geological survey of the site area.



Fig. 6. General view of Table Mountain Observatory grounds looking south

VI. COST ESTIMATE

The cost estimates which follow are based mostly upon conversations during November, 1962, with firms involved in the manufacture of the items listed, and should be quite realistic. The totals are as follows:

Fuzed silica mirror blanks	\$ 60,000	
Figuring of mirrors	50,000	
English equatorial mounting	100,000	
Forty-foot dome, shutters, etc.*	100,000	
Observatory building and special piers	120,000	
Consulting	25,000	
Geological survey	5,000	
Coudé spectrographs	250,000	
		\$710,000

The total expenditure by years would be as follows:

FY '63 Geological survey	\$ 5,000	
Consulting	10,000	
Mirror blanks	60,000	
		\$ 75,000

FY '64 Figuring	\$ 50,000	
Consulting	10,000	
Building and dome	220,000	
Mounting	100,000	
		\$380,000
FY '65 Spectrographs	\$250,000	
Consulting	5,000	
		\$255,000

During 1965 and years following additional auxiliary equipment including Cassegrain spectrographs, infrared radiometers, image converters, etc., should be added. The cost of maintaining and supporting the observatory with the latest equipment, exclusive of salaries, should be at least \$200,000 per year for the first two or three years of operation. Thereafter it is quite possible that this could be reduced considerably.

*This figure is based upon extrapolation of prices quoted for smaller domes a year ago.

VII. PERSONNEL BREAKDOWN OF THE SCIENTIFIC STAFF

Some pertinent facts on the present laboratory staff are summarized as an Appendix. We do not now have a large number of optical and mechanical engineers experienced in telescope design and construction. Since we plan to model our instrument after the Victoria 48-in. reflector we will not need a large supplementary staff,

but no group has such a collection of talent until they begin to build a telescope. Our present consultants, Drs. G. Münch and J. B. Oke of the California Institute of Technology will continue to help in the design stages, and they will, of course, be able to use the telescope after its completion.

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APPENDIX

Scientific Staff

Roland L. Carpenter

Mr. Carpenter has been with JPL since 1959. He was involved in the tracking and orbit determination problems of the *Echo* communications satellite experiment, especially the effects of solar light pressure on its orbit. He was associated with JPL's 1961 Venus radar program and the study of the radar spectra of the planet. He was an experimenter on the 1962 Venus and Mars radar programs.

He received his M.A. from the University of California at Los Angeles in astronomy (1963) and is continuing his studies there toward his Ph.D. degree in astrophysics.

Afton Cayford

Dr. Cayford came to the Laboratory in 1962 to work on the determination of the heating rate in a planetary atmosphere and on other problems connected with model atmospheres. He was previously Assistant Professor of Mathematics at the University of British Columbia and before that did systems analysis for the Hughes Aircraft Co. He received his B.A. degree (1951) from La Verne College and his M.A. (1958) and Ph.D. (1961) from the University of California at Los Angeles.

Warren A. Hovis, Jr.

Dr. Hovis has been at JPL since May, 1962. He is presently engaged in the design and construction of two large absorption tubes for studies of gases prominent in planetary atmospheres. He is also engaged in the development of spectroscopic instrumentation for astronomical telescopes and infrared spectrometers for space probes. Dr. Hovis was previously at General Electric, Missile and Space Vehicle Department, where he did time-resolved spectroscopy of highly ionized plasmas. He received his A.B. (1953) and Ph.D. (1961) in physics from Johns Hopkins University.

At Johns Hopkins, Dr. Hovis studied time-resolved spectra of highly ionized rare Earth ions and for two years was instructor in experimental spectroscopy.

Douglas Jones

Mr. Jones has been at JPL since 1960. He received his B.S. (1957) and M.S. (1959) in physics at Brigham Young University. His work there included the lithium 7 mag-

netic moment in Bohr Magnetons at K band. He is presently an experimenter on the Venus missions—*Mariner R* (1962), *Mariner R F/O* (1964) and *Mariner B*, involving microwave measurements of the planet's temperature. He is presently working toward a Ph.D. in physics at Brigham Young University.

Lewis D. Kaplan

Dr. Kaplan received his Ph.D. in meteorology from the University of Chicago (1951), where he started work in the field of atmospheric heat transfer. He has had a major role in the modern development of this field and, in the past year or two, its application to the atmospheres of planets, particularly Venus. He has been a member of the Institute for Advanced Study as well as the staff of Imperial College, London, and Massachusetts Institute of Technology. He is part-time Professor of Atmospheric Physics at the University of Nevada. He joined JPL in 1961, where he is Staff Scientist to the Lunar and Planetary Sciences Section, working on interpretation of data on planetary atmospheres.

He has been selected as experimenter for the various infrared experiments on Venus and Mars spacecraft.

He is Chairman of the A.G.U. committee on Atmospheric Radiation and Optics; a member of the Planetary Atmospheres Subcommittee and the Committee on Radiation Energy of the American Meteorological Society.

Robert L. Kovach

Dr. Kovach has been at JPL since 1961 working on problems of lunar seismology and the structure of planetary surfaces.

He received his Ph.D. at California Institute of Technology in 1961 in geophysics, his M.A. from Columbia University in 1959, and his B.S. from the Colorado School of Mines in 1955.

Robert V. Meghreblian

Dr. Meghreblian is Chief of the Space Sciences Division and in that capacity is responsible for organizing and directing the major portion of the basic scientific research at the Laboratory and the conception, design, and development of spacecraft scientific instrumentation.

He held the appointment of Associate Professor in Applied Mechanics at the California Institute of Technology during the academic year 1960-1961. He joined the Laboratory in 1958 as Chief of the Physics Section, and was appointed Head of the Physical Sciences Division in 1960.

Formerly he was with the Oak Ridge National Laboratory (1952-1958), where his positions included Associate Director, Gas Cooled Reactor Project; Head of Applied Mechanics Group, ANP Program; Reactor Physicist on the ORNL Research Reactor and Army Package Power Reactor; and Lecturer in Reactor Analysis at ORSORT.

Dr. Meghreblian completed his undergraduate study at Rensselaer Polytechnic Institute in 1943. His graduate work was carried out under a Guggenheim Fellowship at the California Institute of Technology; he received his Ph.D. in aeronautics and mathematics in 1953.

Dr. Meghreblian is co-author of the text *Reactor Analysis* published in 1960 by McGraw-Hill Book Company.

Ray L. Newburn

Mr. Newburn received his B.S. (1954) and M.S. (1955) in astronomy from the California Institute of Technology. Since then he has obtained a number of additional C.I.T. graduate credits. His work there was in the field of observational astrophysics.

He joined JPL in 1956 and has worked in the fields of meteorology, aeronomy, ionospheric physics, and astrophysics of the planets. He is the present supervisor of the Table Mountain Observatory, and is concerned with the operation of the television system for the 1964 Mars *Mariner* probe.

He is a former member of the Astronomy Subcommittee.

Justin J. Rennilson

Mr. Rennilson has been employed at JPL since March, 1961, as a Senior Scientist in the Astronomy Group, Lunar and Planetary Sciences Section of the Space Sciences Division. He is mainly concerned with problems of lunar photometry and spectroscopy.

Mr. Rennilson received an A.B. degree in astronomy from the University of California, Berkeley and Los Angeles in 1950. During 1953-55 he took two years of graduate work toward a Doctorate in the fields of optics,

photometry, and colorimetry at the Optical Institute, Technical University of Berlin, Germany. He was employed by the Visibility Laboratory of the Scripps Institution of Oceanography, University of California at San Diego from 1955-1961 as Associate Engineer in the fields of hydrological and meteorological optics instrumentation. He was a member of the part-time faculty of the Astronomy Department, San Diego State College, 1956-1961 and an observer in IGY Program at San Diego State College, 1957-1959. Mr. Rennilson was consultant to General Dynamics Corporation, Stromberg-Carlson Division, San Diego, 1956-1960.

Takeshi Sato

Dr. Sato received his B.S. (1954) and M.S. (1955) in electrical engineering from the California Institute of Technology. He received a Ph.D. (1960) in electrical engineering from Stanford University, specializing in microwave electronics.

Dr. Sato has been employed at JPL since 1960 as a Senior Research Engineer in the Telecommunications Division, transferring to the Space Sciences Division in 1962.

In the Telecommunications Division, Dr. Sato was responsible for the design, development, and operation of reliable maser systems for deep-space tracking. His work in the Space Sciences Division is with millimeter-wavelength radiometer systems for Mars and planetary investigations.

Ronald Schorn

Dr. Schorn joined the Laboratory in 1962 and is working on planetary radar studies and planetary surface photometry. Dr. Schorn is a graduate of Loyola University of Chicago (1956) and received his M.S. in physics (1958) and Ph.D. in astronomy (1962) from the University of Illinois. While at Illinois he received intensive training in observational astronomy at the Yerkes Observatory of the University of Chicago. Also at Illinois he undertook investigations in radio and radar astronomy and the structure and time variations of the Earth's ionosphere and upper atmosphere.

Hyron Spinrad

Dr. Spinrad joined JPL in 1961. He now specializes in high-resolution spectroscopy of the planets and analysis of the compositions and thermal properties of planetary atmospheres. He obtained his Ph.D. at the University

of California, Berkeley, in 1961, where he was concerned with photoelectric photometry of variable stars and the stellar content of galaxies. Dr. Spinrad held a Lick Observatory Fellowship from 1958-1961 and was Dorothea Klumpke Roberts prize winner in 1959. He is a member of the Astronomy Subcommittee.

Robert Younkin

Mr. Younkin has been with JPL since August, 1961. During this period he was primarily engaged in determining the spectral energy distributions and monochromatic reflectivities of the planets with a scanning monochromator at the Mt. Wilson 60-in. telescope. He has also recently carried out photography of Venus at inferior conjunction.

Prior to coming to JPL he was a member of the technical staff at Space Technology Laboratories (1955-1961). Among the problems he worked on at STL were radiative transfer in planetary atmospheres, determination of reflectivity of local areas of the Moon as a function of phase angle and angles of incidence and reflection, and the effect of the Earth's atmosphere on long-range photography. In addition he has done research on density transients in superheated liquids at the UCLA Engineering Research Laboratory (1952-1953), and in nuclear physics at the University of California Radiation Laboratory (1948-1951).

He holds a B.A. (1947) and M.A. (1951) in physics from the University of California at Berkeley and is doing his Ph.D. Thesis at UCLA.